1. When a cyclin-dependent kinase (Cdk) binds to a cyclin protein, the two form a protein complex that regulates a portion of the cell cycle. Many organisms have multiple types of Cdks and cyclins that work together to guide a cell’s progress through the phases of the cell cycle. One cyclin-Cdk complex is called maturation-promoting factor (MPF). MPF allows the cell to advance from the G₂ stage of the cell cycle to the M phase by activating many other proteins. Another cyclin-Cdk complex, referred to as S-Cdk, activates proteins during the S phase of interphase.

Which prediction would be the most likely response to high levels of S-Cdk complex and low levels of MPF in a cell?

(A) An enzyme that degrades the nuclear envelope would be activated, because this degradation occurs early in the M phase.

Distractor Rationale:
This answer suggests the student may understand that degradation of the nuclear envelope is required before cell division can occur, but does not understand how the components of regulation function together in the cell cycle, because the student does not recognize that the nuclear envelope degrades during mitosis, which would occur when MPF levels in the cell are high and S-Cdk complex levels are low.

(B) An enzyme that initiates DNA replication would be activated, because DNA must be replicated before cell division occurs in the M phase.

Rationale:
This answer suggests the student understands that disassembly of the nuclear envelope, spindle formation, and formation of chromosomes from chromatin occur during the early M phase of the cell cycle, whereas DNA replication occurs during the S phase and, therefore, occurs when S-Cdk complex levels are high and MPF levels are low. The student is able to predict how varying levels of specific components (cyclins and Cdks) influence the timing of the cell cycle and the sequencing of events that results in the passage of heritable information from one generation to the next.

(C) An enzyme that initiates the tight coiling of chromatin into thick threads would be activated, because this coiling occurs before chromosomes can be divided.
2. Cyclin-dependent kinase (Cdk) and cyclin work together to regulate the cell cycle. The diagram below shows the levels of Cdk and cyclin throughout the cell cycle.

Which statement best explains how Cdk and cyclin control the cell cycle?
(A) Cdk and cyclin are synthesized during the S and G\textsubscript{2} phases and degrade at the end of the M phase, because both proteins need to be present in high levels for the cell to enter the M phase and both must degrade for the cell to enter the G\textsubscript{1} phase.

*Distractor Rationale:*
This answer suggests the student may understand that both Cdk and cyclin must be present in high levels for cells to divide, but *does not understand* how the components of regulation function together in the cell cycle, because the student *does not recognize* that Cdk is not degraded at the end of the M phase, given that it remains at high levels throughout the cell cycle.

(B) An allosteric inhibitor binds to Cdk at the end of the M phase and allows the cell to enter the G\textsubscript{1} phase, because without the inhibition of Cdk, the cell would remain in the M phase and be unable to grow.

*Distractor Rationale:*
This answer suggests the student may understand that Cdk and cyclin must both be activated before a cell can divide, but *does not understand* how the components of regulation function together in the cell cycle, because the student *does not recognize* that regulation of Cdk is not a plausible explanation for how Cdk and cyclin control the cell cycle, based on the fact that it is the degradation of cyclin that allows the cell to enter the G\textsubscript{1} phase.

(C) Cyclin is synthesized during the S and G\textsubscript{2} phases and is degraded at the end of the M phase, so the cyclin-Cdk complex cannot continue to regulate mitotic processes and the cell enters the G\textsubscript{1} phase.

*Rationale:*
This answer suggests the student *understands* that synthesis and degradation of cyclin serve as the regulating processes in the timing of the cell cycle. Cdk requires the presence of cyclin in order to continue to regulate mitotic processes in the cell; thus, the degradation of cyclin during the M phase takes the cell into the next phase of the cell cycle, G\textsubscript{1}. In this way, cyclin and Cdk are components that ensure that the conditions are correct to proceed and that the next phase occurs only when the cell has completed all the necessary steps in order to accurately pass heritable information to its daughter cells during cell division.

(D) As levels of cyclin increase throughout the M phase, cyclin serves as a negative feedback inhibitor by blocking the function of Cdk so that the M phase ceases and the G\textsubscript{1} stage begins.
3. A researcher is trying to determine the changes that nerve cells undergo as they age. When fully mature, nerve cells are incapable of dividing, and, therefore, nerve tissue cannot regenerate. The diagram below shows three checkpoints at which regulatory proteins control the cell cycle.

Which hypothesis best explains how nerve cells become incapable of cell division?

(A) Mature nerve cells do not produce the proteins required for the cycle to proceed through the M checkpoint, which is required for cells to complete cell division.

Distractor Rationale:
This answer suggests the student may understand that proceeding through the M checkpoint is required for cells to complete the cell cycle, but does not understand how to apply the functions of the components of interphase to the cell cycle, because the student does not recognize that the key checkpoint in this cycle is the G\textsubscript{1} checkpoint and that it is at this checkpoint that cells either proceed through cell division or remain in a non-dividing state.
(B) Mature nerve cells do not produce the proteins required for the cycle to proceed through the G₁ checkpoint, which allows cells to either proceed through cell division or remain in a non-dividing state.

**Rationale:**

This answer suggests the student **understands** that the G₁ checkpoint is the point at which it is decided if cells will proceed through cell division or remain in a non-dividing state. Mature nerve cells do not produce the proteins necessary to pass through the G₁ checkpoint and continue into cell division. An understanding of the events that function to regulate the timing of the cell cycle, such as checkpoints and regulatory components, helps to explain why nerve tissue is incapable of regenerating.

(C) Mature nerve cells do not produce the proteins required for the cycle to proceed through the G₂ checkpoint, which is required for cells to initiate cell division.

**Distractor Rationale:**

This answer suggests the student may understand that proceeding through the G₂ checkpoint is required for cells to complete the cell cycle, but **does not understand** how to apply the functions of the components of interphase to the cell cycle, because the student **does not recognize** that the key checkpoint in this cycle is the G₁ checkpoint and that it is at this checkpoint that cells either proceed through cell division or remain in a non-dividing state.

(D) Mature nerve cells do not produce the proteins required for the cycle to proceed through the G₀ phase to completion and undergo different forms of cell growth that are prerequisites for cell division.

**Distractor Rationale:**

This answer suggests the student may understand that proceeding through specific checkpoints and phases is required for cells to complete the cell cycle, but **does not understand** that G₀ is a stage in which the cell is neither dividing nor preparing to divide. Mature nerve cells do not produce the proteins necessary to pass through the G₁ checkpoint and, thus, stay in the G₀ phase indefinitely. The student **may not understand** how to apply the functions of the components of interphase to the cell cycle, because the student **does not recognize** that the key checkpoint in this cycle is the G₁ checkpoint and that it is at this checkpoint that cells either proceed through cell division or remain in a non-dividing state.

**Aligned to:** LO 3.11 CA 3.11: Evaluate DNA Transmission Data
Researchers want to see what will happen if two cells in different stages of the cell cycle are combined into one cell. The researchers fuse cells in different stages of the cell cycle and observe changes within the nuclei of each new cell. The results of the experiments are shown below.

Based on the results of the experiments, which conclusion best describes how the cell cycle is controlled?

(A) If a G₁ cell is fused with a cell in the S or M stage, the G₁ cell will enter the S or M stage because molecules in the S and M cells control the progression to those stages.

Rationale:
This answer suggests the student understands that regulatory molecules in the cytoplasm control changes in the nucleus, which, in turn, controls the cell cycle. In this experiment, it is shown that regulatory molecules found in the cytoplasm of the cells in the S or M stage ultimately dictate which stage the G₁ cell will progress to. The student understands that certain components of interphase, such as the regulatory molecules that determined the outcome of these experiments, are responsible for the timing of the cell cycle and the eventual transmission of heritable information during cell division.

(B) If a G₁ cell is fused with a cell in the S or M stage, the G₁ cell will enter the S or M stage because the G₁ DNA will receive signals from the DNA of the other nucleus.
Distractor Rationale:

This answer suggests the student may understand that if cells in various stages of the cell cycle are fused, cells in the S and M stages will cause changes in the \( G_1 \) nucleus, but does not understand how to apply the functions of the components of interphase to the cell cycle, because the student does not recognize that the changes in the \( G_1 \) nucleus are due to regulatory proteins in the cytoplasm, not the DNA.

(C) If a \( G_1 \) cell is fused with a cell in the S or M stage, the \( G_1 \) cell will enter the S or M stage because the cell membrane will detect the increased volume of the cell.

Distractor Rationale:

This answer suggests the student may understand that if cells in various stages of the cell cycle are fused, cells in the S and M stages will cause changes in the \( G_1 \) nucleus, but does not understand how to apply the functions of the components of interphase to the cell cycle, because the student does not recognize that the changes in the \( G_1 \) nucleus are due to regulatory proteins in the cytoplasm, not the cell membrane, as these changes did not occur when two \( G_1 \) cells were fused.

(D) If a \( G_1 \) cell is fused with a cell in the S or M stage, the \( G_1 \) cell will enter the S or M stage because the \( G_1 \) cell will detect that there is too much cytoplasm and that the cell should divide.

Distractor Rationale:

This answer suggests the student may understand that if cells in various stages of the cell cycle are fused, cells in the S and M stages will cause changes in the \( G_1 \) nucleus, but does not understand how to apply the functions of the components of interphase to the cell cycle, because the student does not recognize that the changes in the \( G_1 \) nucleus are due to regulatory proteins in the cytoplasm, not the changes in cytoplasm volume, as these changes did not occur when two \( G_1 \) cells were fused.

Aligned to: LO 3.11 CA 3.11: Evaluate DNA Transmission Data